



The influence of low frequency and infrasonic noise on man

Møller, Henrik

Published in:

The question of sound from icebreaker operations: The Proceedings of a workshop, Toronto, Ontario, February 23-24, 1981

Publication date:

1981

[Link to publication from Aalborg University](#)

Citation for published version (APA):

Møller, H. (1981). The influence of low frequency and infrasonic noise on man. In *The question of sound from icebreaker operations: The Proceedings of a workshop, Toronto, Ontario, February 23-24, 1981* (pp. 310-319)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal -

Take down policy

If you believe that this document breaches copyright please contact us at vbn@aub.aau.dk providing details, and we will remove access to the work immediately and investigate your claim.

THE INFLUENCE OF LOW FREQUENCY AND INFRASONIC NOISE ON MAN

Henrik Møller

Institute of Electronic Systems
Aalborg University Centre
Aalborg, Denmark

It is quite obvious that noise at low frequencies (20 to 200 Hz) and infrasound (below 20 Hz) will be an important part of the total noise levels generated by the proposed LNG tankers. Not only do the ships emit considerable amounts of acoustic power at these frequencies, the propagation loss of ship noise at these low frequencies is very low.

During the last 10 to 15 years, several effects of low frequency and infrasonic noise on human beings have been demonstrated, ranging from slight annoyance at low sound pressure levels to severe physiological effects at very high levels. The effects on humans cannot be directly applied to marine mammals such as whales and seals, especially not for specific frequencies and sound pressure levels. However, it is important to be aware of these potential effects and to evaluate them in relation to marine mammals. The present paper does not provide such an evaluation but does present a short summary of the effects on human beings, without going into details about frequencies and levels.

The most well-known effects are those on the hearing capability of humans. Among these effects are masking of "wanted" sound (Alford et al 1966, Connor and Yeowart 1974, Doroshenko and Palgov 1975, Yeowart 1973), for example vocal communication, which is the subject of several other contributions to this workshop. Other effects are disturbance of the hair cells in the inner ear which causes temporary or permanent hearing impairment (Alford et al 1966; Coles and Guignard 1965; Doroshenko and Palgov 1975; Hood, Kyriakides and Leventhall 1971; Lidström and Liszka

From: The Question of Sound from Icebreaker Operations:

The Proceedings of a Workshop.

February 23 and 24, 1981

Toronto, Ontario

Edited by N. Merle Peterson

Western Ecological Services (B.C.) Ltd.

Sponsored by Arctic Pilot Project

Petro Canada

1976; Nixon 1973), pain from overloading of the middle ear (Cole et al 1965; Davis et al 1953; Evans 1976) and, at very high levels, rupture of the tympanic membrane (Johnson 1973 for data from a chinchilla). Also, disturbance of the vestibular system may result in balance disturbance and nystagmus (Alford et al 1966; Bazarov, Doroshenko and Palgov 1977; Bryan, Evans and Tempest 1972; Cole et al 1965; Davis et al 1953; Evans and Tempest 1972; Hood, Kyriakides and Leventhall 1971; Okai et al 1980; Yeowart 1971; on animals: Gierke, Parker and Reschke 1970 and Gierke and Parker 1971). These effects are probably induced by liquid flow through the small endolymphatic duct between the cochlea and the vestibularis.

Because of resonances in the lungs, stomach and other compressible parts of the body, unpleasant and possibly dangerous tissue vibrations may also result from low frequency sound. The Helmholtz resonator effect created by the lungs and throat may cause disturbances of respiration (Alford et al 1966; Barthelemy et al 1971; Cole et al 1965; Evans 1976; Grognot 1969; Okai et al 1980) which at very high pressure levels has even caused cessation of breathing in a dog; the dog did not die because the sound itself provided sufficient air exchange in the lungs (Johnson 1973).

Although it is generally believed that human hearing has a limiting frequency of 16 to 20 Hz, this is, in fact, not true. The human ear is able to detect sounds with frequencies at least down to 1 to 2 Hz (Békésy 1960; Bryan, Tempest and Yeowart 1967; Bryan, Tempest and Yeowart 1969; Collins, Robinson and Whittle 1972; Evans and Yeowart 1974; Franke and Dancer 1980; Gierke and Johnson 1974; Guttman and Julesz 1963; Okai et al 1980; Rubak 1980; Yeowart 1971; Yeowart 1976). For these infrasonic frequencies, the hearing threshold level is higher than for the normal hearing range (Figure 1).

An important feature of infrasound is that it only needs to be slightly above the hearing threshold level to be subjectively loud and annoying (Bryan 1976; Bryan and Tempest 1979; Gordon and Vasudevan 1977; Leventhall 1980; Tempest 1973; Yamada et al 1980). This annoyance may be the source of some effects on task performance (Evans and Tempest 1972; Hood, Kyriakides and Leventhall 1971; Kyriakides and Leventhall 1977; Landström

1980; Møller 1980) and some stress-like physiological effects observed in humans experiencing infrasound exposure, such as changes in blood pressure, heart rate, EEG and production of certain hormones (Alford et al 1966; Barthelemy et al; 1971; Borredon and Nathalie 1973; Cole et al 1965; Edge and Mayes 1966; Grognot 1969; Ising 1980; Landström 1980; Lidström and Liszka 1976; Okai et al 1980).

Only in a few countries do maximum limits on infrasonic exposure exist (Arbetarskyddsstyrelsen 1978; Arbeidstilsynet 1979; Brüel 1980; Gierke 1977). In the writer's opinion, the most reasonable limits on infrasonic exposure are those guidelines recommended in the United States (Gierke 1977). They provide two sets of limits (Figure 2). Limit A is intended to prevent direct physiological effects and is applicable for exposure times below 1 minute. Limit B is intended to prevent annoyance effects and is applicable for exposure times above 100 minutes. For exposure times between 1 and 100 minutes, an interpolation procedure is given. Limits are recommended for pure tone exposure but it is not stated how broadband noise should be measured. A possible solution would be measurements in the 1/3 or 1/1 octave bands.

Recommended limits for underwater exposure of marine mammals to low frequency and infrasound are completely uncertain. There are several reasons for not using the same limits as for human beings. However, these limits are the only ones available. Figure 3 illustrates the expected 1/1 octave sound pressure levels at two different distances from an LNG carrier cruising at a speed of 4 kt in heavy ice. The reader is free to make his own comparison of Figures 2 and 3.

REFERENCES

- Alford, Bob R., John Billingham, A.C. Coats, B.O. French, James F. Jerger, R.O. McBrayer. 1966. Human tolerance to low frequency sound. Transactions of American Academy of Ophthalmology and Otolaryngology 70:40-47.
- Arbetarskyddsstyrelsen. 1978. Infraljud och ultraljud i arbetslivet. Arbeterskyddsstyrelsens anvisningar nr. 110:1, Stockholm.

- Arbeidstilsynet, Direktoratet for: 1979. Utkast til generelle forskrifter om støy på arbeidsplassen. Oslo 30.3.
- Barthelemy, R., J. Bourgoïn, H. Eberle, R. Fecci, G. Jullien, A. Mathias, A. Moutel. 1971. L'action des infra-sons sur l'organisme. *Medicine del Lavoro*, 62:130-150.
- Bazarov, V.G., P.N. Doroshenko, V.I. Palgov: 1977. Condition of vestibular function in compressor operators exposed to infrasound and stable noise. (In Russian, English abstract). *Zhurnal Ushnykh Nosovykh Gorlovykh Boleznei*, 37(3):54-59.
- Békésy, G. von. 1936. Über die hörschwelle und füllgrenze langsamer sinusförmiger luftdruckschwankungen. *Annalen der Physik*, 5. Folge, Band 26, 554-566. Low-frequency thresholds for hearing and feeling. English translation in: E.G. Wever, Editor. 1960. *Experiments in Hearing*. McGraw-Hill, New York. p. 257-267.
- Borredon, P. and J. Nathie. 1973. Effets physiologiques observés chez l'homme exposé à des niveaux infrasonores de 130 dB. IN: *Colloque International sur les Infrasons*, 24-27 septembre, Paris. L. Pimonov, Editor. p. 61-84.
- Brown, F.D., K. Kyriakides, H.G. Leventhall. 1977. Somatic response to low frequency noise. The 9th International Congress on Acoustics, Madrid, 4-9 July.
- Brüel, P. V. 1980. Standardization for low frequency noise measurements. IN: *Proceedings of Conference on Low Frequency Noise and Hearing*, 7-9 May 1980 in Aalborg, Denmark. H. Møller and P. Rubak, Editors.
- Bryan, M.E. 1976. Low frequency noise annoyance. IN: *Infrasound and Low Frequency Vibration*. W. Tempest, Editor. Academic Press, London.
- Bryan, M.E., W. Tempest and N. S. Yeowart. 1967. The monaural M.A.P. threshold of hearing at frequencies from 1.5 to 100 c/s. *Journal of Sound and Vibration* 6(3):335-342.
- Bryan, M.E., W. Tempest and N. S. Yeowart. 1969. Low frequency noise thresholds. *Journal of Sound and Vibration* 9(3):447-453.
- Bryan, M.E., M.J. Evans and W. Tempest. 1971. Clinical applications of low frequency sound. *Sound* 5:47-51.
- Bryan, M.E. and W. Tempest. 1979. Low frequency noise annoyance. IN: *Institute of Acoustics Meeting on Low Frequency Noise*, 5th January 1979, Chelsea College, London.
- Cole, J. N., H. E. von Gierke, E. Guild and G. C. Mohr. 1965. Effects of low frequency and infrasonic noise on man. *Aerospace Medicine* 36(9):817-824.

- Coles, R.A.A. and J.C. Guignard. 1965. Effects of infrasonic vibration on the hearing. Proceedings of the 5th International Congress of Acoustics, B57, Liege 1965.
- Collins, S.J., S.W. Robinson and L.D. Whittle. 1972. The audibility of low frequency sounds. Journal of Sound and Vibration 21(4):431-448.
- Connor, P.E. and N.S. Yeowart. 1974. The effect of infrasonic and very low frequency noise on speech intelligibility. Applied Acoustics 7:229-231.
- Davis, H., D.H. Eldredge, H.E. von Gierke and J.D. Hardy. 1953. Aural pain produced by sound. IN: An exploratory study of the biological effects of noise. Benox report, contract N6 ori-020, task order 44, ONR project nr. 144079, University of Chicago.
- Doroshenko, P.N. and V.I. Palgov. 1975. Combined effects of infrasound and stable noise of the hearing function of compressor shop operators. (In Russian, English abstract). Zhurnal Ushnyk Nosovykh I Gorlovykh Bolezne, 35(1):22-28.
- Edge, P. M. and W. H. Mayes. 1966. Description of Langley low-frequency noise facility and study of human response to noise frequencies below 50 cps. NASA Technical Note D-3204, National Aeronautics and Space Administration, Washington D.C., January 1966.
- Evans, M. J. and W. Tempest. 1972. Some effects of infrasonic noise in transportation. Journal of Sound and Vibration 22(1):19-24.
- Evans, M. J. and N.S. Yeowart. 1974. Thresholds of audibility for very low-frequency pure tones. Journal of the Acoustical Society of America 55(4):814-818.
- Evans, M. J.. 1976. Physiological and psychological effects of infrasound at moderate intensities. IN: Infrasound and Low Frequency Vibration. W. Tempest, Editor. Academic Press, London.
- Franke, R. and Dancer A.. 1980. Cochlear microphonic potential and intracochlear sound pressure measurements at low frequencies in guinea pigs. IN: Proceedings of Conference on Low Frequency Noise and Hearing, 7-9 May 1980 in Aalborg, Denmark. H. Møller and P. Rubak, Editors.
- Gierke, H. E. von, D.E. Parker and M.F. Reschke. 1970. Stimulation of the vestibular apparatus in the guinea pig by static pressure changes: head and eye movements. Journal of the Acoustical Society of America, 48(4):913-923.
- Gierke, H. E. von and D.E. Parker. 1971. Vestibular nerve response to pressure changes in the external auditory meatus of the guinea pig. Acta Otolaryng, 71:456-461.

- Gierke, H. E. von and D. L. Johnson. 1974. Audibility of infrasound. 88th Meeting of the Acoustical Society of America, 1974. Abstract in Journal of the Acoustical Society of America 56, Supplement, S37.
- Gierke, H. E. von. 1977. Guidelines for preparing environmental impact statements on noise. Report of Working Group 69 on Evaluation of Environmental Impact of Noise. Committee on Hearing, Bioacoustic and Biomechanics. National Academy of Sciences, Washington, D.C., 1977.
- Gordon, C. G. and R.N. Vasudevan. 1977. Experimental study of annoyance due to low frequency environmental noise. Applied Acoustics 10(1):57-69.
- Grognot, P. 1969. Reaction physiopathologiques de l'être humain exposé à des infra-sons appliqués par voie auriculaire. Journées Françaises d'Environnement, Ecole Nationale Supérieure de l'Aéronautique, Paris, France, 31 mars-1 avril, 1969, p. 83-91.
- Guttman, N. and Bela Julesz. 1963. Lower limits of auditory periodicity analysis. Journal of the Acoustical Society of America 35:610 (letters to the Editor).
- Hood, R.A., K. Kyriakides and H.G. Leventhall. 1971. Some subjective effects of noise. British Acoustical Society Meeting on Infrasound, 26th November 1971, University of Salford.
- Ising, H. 1980. Psychological, ergonomical and physiological effects of long-term exposure to infrasound and audiosound. IN: Proceedings of Conference on Low Frequency Noise and Hearing, 7-9 May 1980 in Aalborg, Denmark. H. Møller and P. Rubak, Editors.
- Johnson, D. L. 1973. Various aspects of infrasound. Colloque International sur les Infra-sons, 24-27 septembre 1973, Paris. L. Pimonov, Editor. p 337-358.
- Johnson, D. L. and R.N. Slarve. 1975. Human whole-body exposure to infrasound. Aviation, Space and Environmental Medicine 46(4):428-431.
- Kyriakides K. and H.G. Leventhall. 1977. Some effects of infrasound on task performance. Journal of Sound and Vibration 50(3):369-388.
- Landström, U. 1980. Some effects of infrasonic noise on man. IN: Proceedings of Conference on Low Frequency Noise and Hearing, 7-9 May 1980 in Aalborg, Denmark. H. Møller and P. Rubak, Editors.
- Leventhall, H.G. 1973. Man-made infrasound - its occurrence and some subjective effects. Colloque International sur les Infra-sons, 24-27 septembre 1973, Paris. L. Pimonov, Editor. p 129-152.

- Leventhall, H.G. 1980. Annoyance caused by low frequency/low level noise. IN: Proceedings of Conference on Low Frequency Noise and Hearing, 7-9 May 1980 in Aalborg, Denmark. H. Møller and P. Rubak, Editors.
- Lidström, I. M. and L. Liszka. 1976. Infraljud i arbetsmiljön. Arbetsarskyddsnämnden, Sweden.
- Møller, H. 1980. The influence of infrasound on task performance. IN: Proceedings of Conference on Low Frequency Noise and Hearing, 7-9 May 1980 in Aalborg, Denmark. H. Møller and P. Rubak, Editors.
- Nixon, C. W. Human auditory response to intense infrasounds. Colloque International sur les Infra-sons, 24-27 septembre 1973, Paris. L. Pimonov, Editor. p 315-335.
- Okai, O., M. Saito, M. Taki, A. Mochizuki, N. Nichiwaki, T. Mori, and M. Fujio. 1980. Physiological parameters in human response to infrasound. IN: Proceedings of Conference on Low Frequency Noise and Hearing, 7-9 May 1980 in Aalborg, Denmark. H. Møller and P. Rubak, Editors.
- Rubak, P. 1980. Low frequency models for mechanical to neural transduction. IN: Proceedings of Conference on Low Frequency Noise and Hearing, 7-9 May 1980 in Aalborg, Denmark. H. Møller and P. Rubak, Editors.
- Tempest, W.: 1973. Loudness and annoyance due to low frequency sound. *Acustica* 29:205-209.
- Yamada, S., T. Kosaka, K. Bunya, and A. Toshihiko 1980. Hearing of low frequency sound and influence on Human body. IN: Proceedings of Conference on Low Frequency Noise and Hearing, 7-9 May 1980 in Aalborg, Denmark. H. Møller and P. Rubak, Editors.
- Yeowart, N. S. 1971. Low frequency threshold effects. IN: British Acoustical Society Meeting on Infrasound, 26th November 1971, University of Salford.
- Yeowart, N. S. 1973. The effects of infrasound on man. IN: Colloque International sur les Infra-sons, 24-27 septembre 1973, Paris. L. Pimonov, Editor. p 289-306.
- Yeowart, N.S. 1976. Threshold of hearing and loudness for very low frequencies. IN: *Infrasound and Low Frequency Vibration*. W. Tempest, Editor. Academic Press, London.

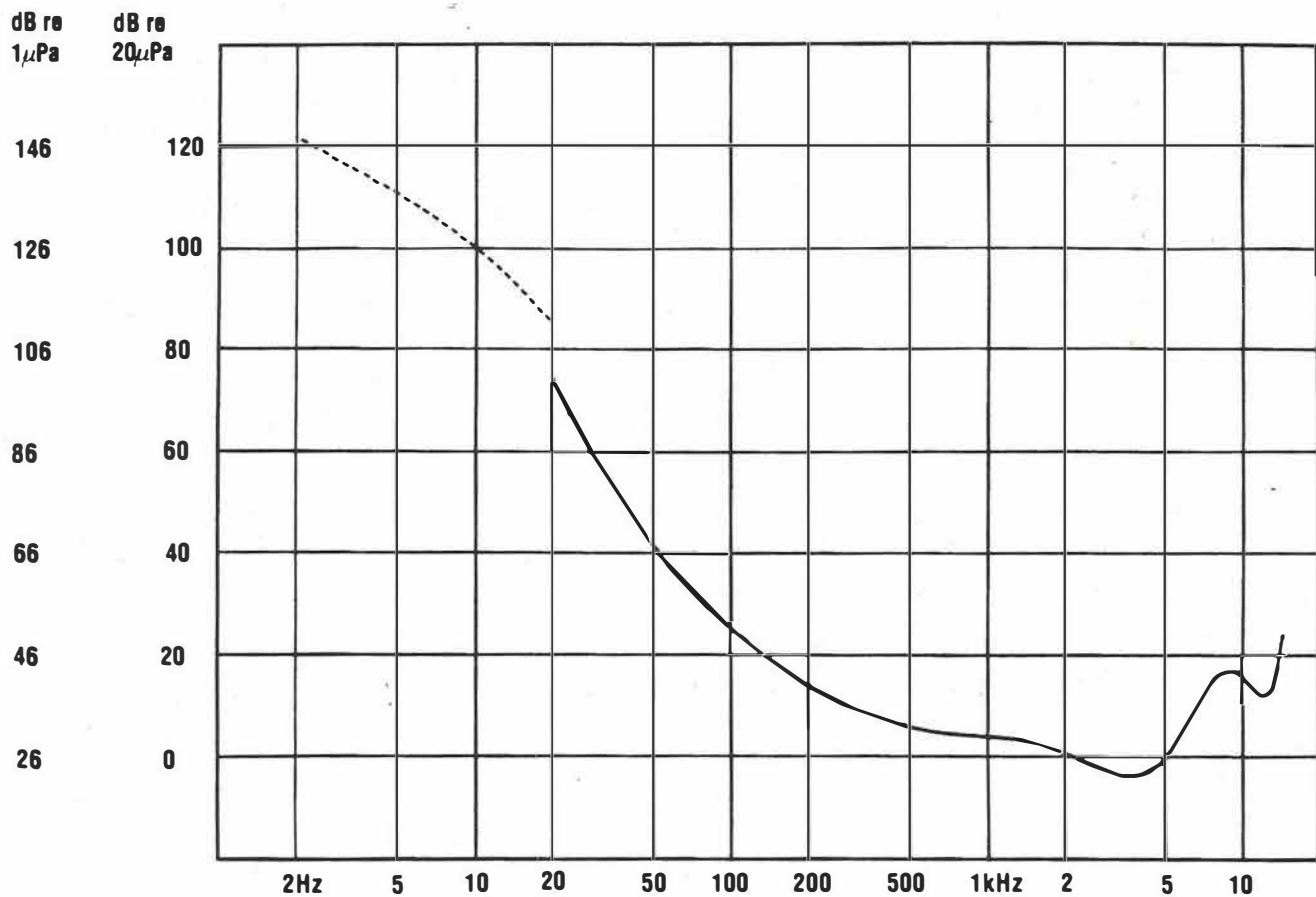


Figure 1. Hearing threshold level of the human ear stimulated by pure sinusoidal tones. The solid line is a standardized curve (ISO - 226), while the dotted line is based on data from Evans and Yeowart (1974).

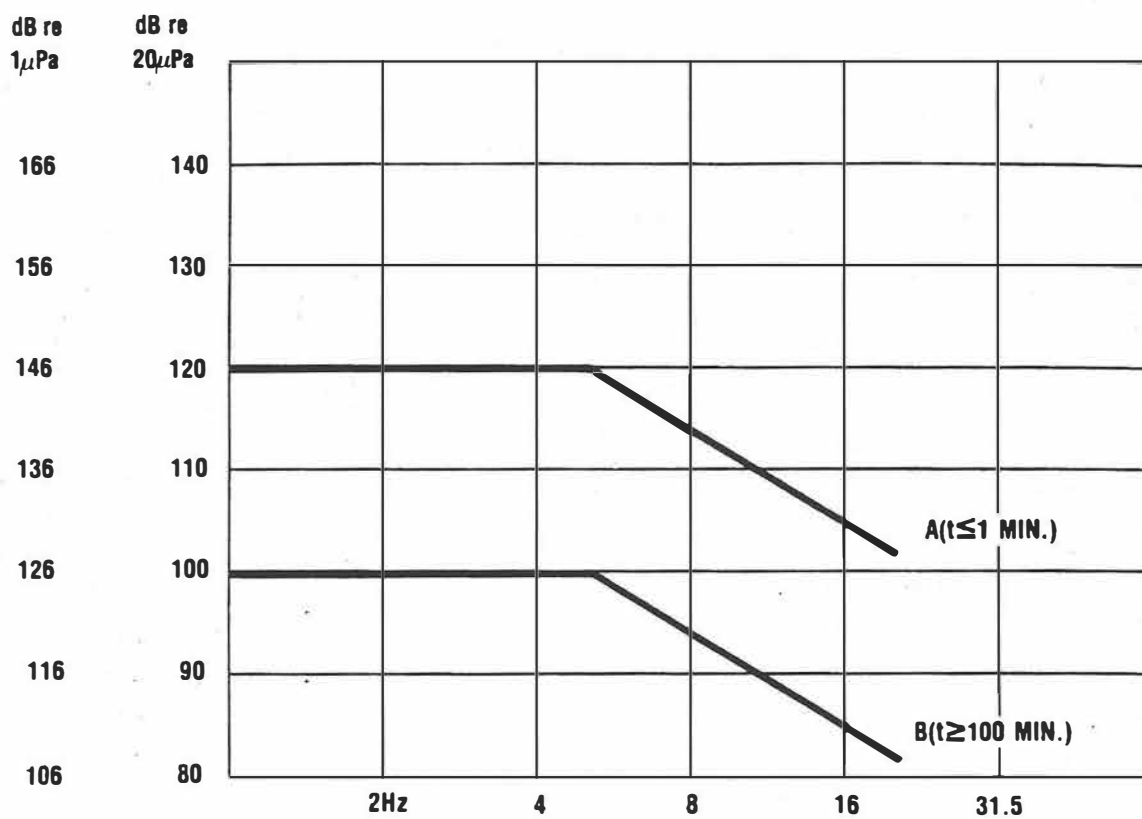


Figure 2. Recommended maximum limits for human exposure to pure tones (Gierke 1977)

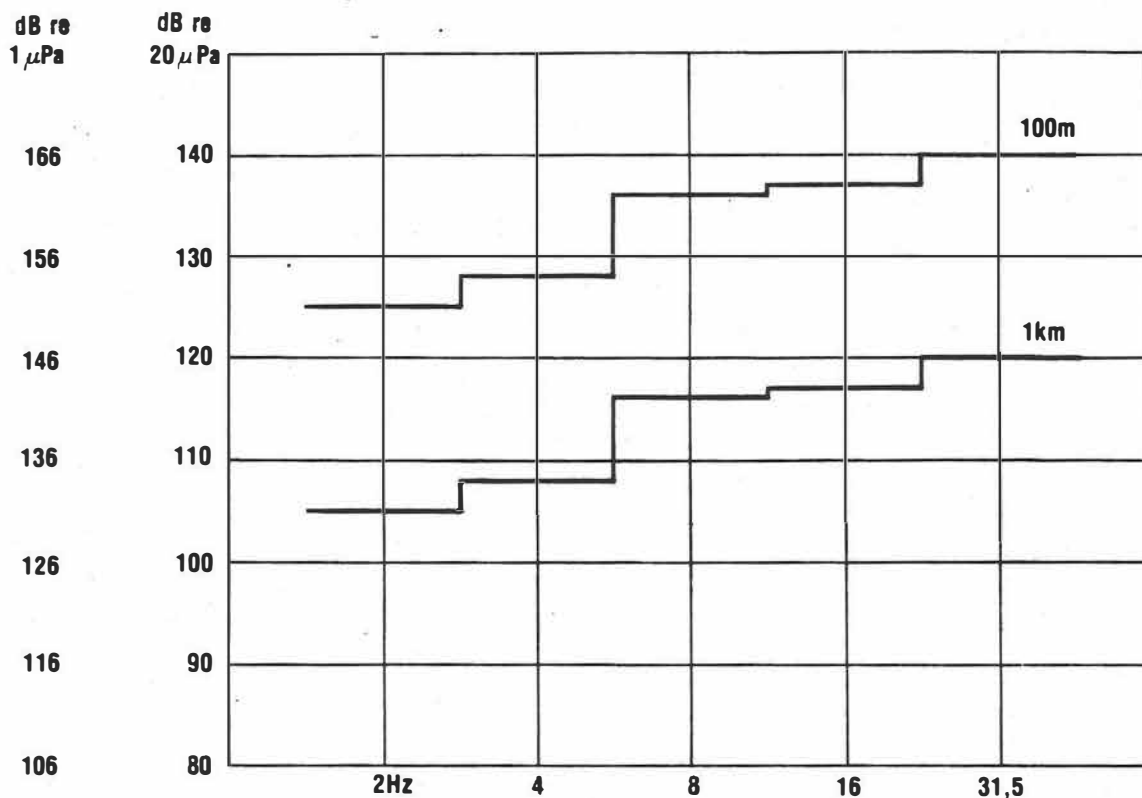


Figure 3. Expected 1/1 octave sound pressure levels in two distances from the ship cruising at a speed of 4 knots in heavy ice. Figures are based on the source levels agreed upon at the workshop: (a) broadband noise of the spectral density being flat at a level of 189 dB re 1 μ Pa Hz^{1/2} below 50 Hz and above this decreasing 20 dB per decade; plus (b) pure tones at 8.6 Hz and harmonics of that, the first three being 201 dB each, and from the fourth decreasing 5 dB per harmonic.